

“Energy-Efficient Operational Transconductance Amplifier in CMOS for Bluetooth and Wi-Fi Applications”

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Abstract—In today's digital economy, the internet serves as the connective thread for billions of individuals, facilitating communication and access to information on a global scale. This widespread connectivity is predominantly achieved through wireless communication technologies, representing a key driver for the benefits realized in our interconnected world. Essentially, concurred guidelines for cell phones permit people to utilize their gadgets wherever on the planet. For wireless communication Bluetooth and WiFi technology is mainly used to connect the gadgets. Operational Transconductance Amplifiers (OTAs) are essential components in circuit design for Bluetooth and WiFi applications, serving as key elements in signal processing. With their utilization of CMOS technology, OTAs provide adaptable solutions known for their capability to convert voltage signals into current signals. This introductory overview delves into the vital role of OTAs in optimizing the performance and efficiency of Bluetooth and WiFi systems, underscoring their pivotal application in contemporary wireless communication technologies. The Bluetooth and WiFi both work on the 2.4 GHz frequency. In this paper present a cascade current mirror operational transconductance amplifier design for wireless Bluetooth and WiFi application using CMOS 90nm environment.

Keywords—OTA, CMOS, Current Mirror, Cascade, WiFi, Bluetooth

I. INTRODUCTION

In the mid 1990s, RF integrated circuits (RFICs) were overwhelmed by bipolar and GaAs innovations, while CMOS advancements were principally utilized for band signal applications. As the network lengths of CMOS gadgets were decreased to one micron during the 1990s, CMOS RFIC over GHz became conceivable. From that point forward, the proceeded with decrease of CMOS gadgets to the present submicron gadgets has introduced another period for CMOS RFIC plans, including OTA circuits [1]. In the past few decades the technology has transformed from the passive device which were used in wireless telecommunication to the vast variety of active filters VLSI circuits, employed from High frequency space engineering to very small frequency applications [2]. From bulky vacuum tubes the circuits have evolved to micro silicon chips, which are now emerging in the dimensions of nanotechnology [3]. Along with this the responsibility towards the reduced consumption of power and

supply voltage demand has also increased. The downscaling of circuits has made it important that they consume least amount of voltage and power [4-5].

In the last 20 years the portable devices such as laptops, smart phone have become an important part of daily life, the technology is enhancing at a very high speed and with this the requirement of low power low voltage circuits has also raised [6-7]. As the majority of devices rely on batteries for operation, it has become essential to devise circuits that minimize both supply voltage and current consumption. Even a slight reduction in either of these factors can lead to extended battery life, thereby enhancing the product's value and improving its viability, particularly in critical applications such as biomedical devices [8-9]. These devices often require connectivity to wireless networks such as Bluetooth and Wi-Fi, necessitating the use of a transceiver. Consequently, there is a pressing need for the development of transceiver devices capable of operating at lower voltages, reflecting the current demands of the times. Because of the new improvement of VLSI innovation and in the field of microelectronics, the size of the semiconductor diminishes and the power supply additionally diminishes [10]. Operational Transconductance Amplifiers (OTAs) assumed a vital part in the acknowledgment of the circuit because of their different invaluable highlights, for example, electronic change of transconductance gain, higher transfer speed, high reaction speed, low power utilization, little chip size and low inventory voltage [11].

In today's digital era, wireless communication technologies, notably Bluetooth and WiFi, are fundamental for ensuring smooth connectivity. Operational Transconductance Amplifiers (OTAs) assume a pivotal role in fine-tuning the performance of wireless systems. This study delves into the intricacies of designing and applying OTAs, with a specific focus on their adaptation for Bluetooth and WiFi applications. Through the exploration of inventive methodologies in this domain, the research strives to provide valuable perspectives aimed at elevating the effectiveness and connectivity of these omnipresent technologies.

OTA have various benefits in WiFi and Bluetooth applications such as high linearity ensures precise signal processing, wide bandwidth accommodates diverse frequency ranges, low power consumption extends battery life, compact

size suits integration into circuits, versatility supports multiple functions like amplification and filtering. In this paper present an OTA design using the CMOS 90nm technology in LTSpice software for Bluetooth and WiFi applications. The presented OTA is work on the 2.4GHz frequency range that is used for the both Bluetooth and WiFi.

II. RELATED WORKS

Recent studies have focused on refining OTA designs tailored for Bluetooth applications. Kim et al. (2023) investigated advanced OTA design techniques, stressing the significance of attaining low power consumption and high linearity to address the requirements of contemporary Bluetooth-enabled devices. Their findings offer valuable insights into navigating the complex interplay of performance metrics essential for integrating Bluetooth systems effectively [12]. Kulej et al. (2022) introduces an innovative approach to designing an ultra-low-voltage linear OTA. The circuit employs a non-tailed, differential stage class AB combined with an extra linear resistor. This combination effectively suppresses the 3rd order harmonic component, leading to a highly linear DC transfer characteristic. Notably, this enhanced linearity is achieved without any additional power consumption, making the circuit efficient and suitable for low-voltage applications. Fabricated using a $0.13\mu\text{m}$ CMOS process and powered by a VDD of 0.3V, the circuit offers a rail-to-rail input range with total harmonic distortion below 0.5% for a nominal transconductance of $2.93\mu\text{S}$. Moreover, the transconductance is tunable from $1.41\mu\text{S}$ to $5.72\mu\text{S}$ while maintaining rail-to-rail input swing and total harmonic distortion below 1%. [13]. Shankar et al. (2022) explains the OTA design using CMOS 90nm for WiFi both the frequency band 2.4 and 5GHz application. in this work explain and shown the all the results of the proposed design in the term of current, group delay, frequency response, phase margin and power consumption. In this design the power consumption is 43.26GHz for both 2.4 and 5GHz WiFi application [14]. OTA-based transceivers play a crucial role in WiFi communication systems, providing benefits in performance and integration. In their study, Li et al. (2022) introduced an innovative OTA architecture combined with a high-speed voltage-controlled oscillator (VCO) for WiFi transceivers, showcasing improved signal integrity and energy efficiency. This research significantly contributes to advancing high-performance WiFi solutions across diverse applications [15]. Song et al. (2021) introduces a 2.4-GHz low-power single-quadrature low-IF BLE receiver for IoT applications. It features a quadrature local oscillator (LO) buffer, eliminating extra LO circuitry and reducing DC current consumption. Fabricated using a 65-nanometer CMOS process, the receiver demonstrates remarkable performance metrics. It boasts a noise figure of 8.16dB, a conversion gain of 54.5dB, and an image rejection ratio of 32.1dB. Drawing a bias current of 2.5mA from a 0.8 V supply, the receiver occupies a compact active die area of 1.65 square millimeters. This design offers a simple, low-power solution for BLE applications, with enhanced performance and efficiency suitable for IoT devices [16]. Hu et al. (2021) present a novel and compact Bluetooth low energy compliant receiver architecture that surpasses the 1mW power consumption barrier with 28-nm CMOS technology. In this design by utilizing an inverter-based, inductor-free low-noise transconductance amplifier, they achieve notable enhancements, notably boosting ACR by 1.5/2.5dB at 2/3MHz offset. Through strategic use of current-reuse and switched-capacitor circuitry, their RX achieves

outstanding figures of merit of 183.2dB alongside a sensitivity of -93.2dBm , marking it as best-in-class [17]. Prasad et. al. presents a novel GmC complex filter approach for Bluetooth wireless receiver applications, emphasizing a high Image Rejection Ratio (IRR). Unlike conventional methods, it achieves the desired IRR with fewer stages, enhancing the filter's quality factor (Q) while consuming less power. Targeting BLE receivers with a 4MHz center frequency, the filter utilizes OTAs operating at a 1.8 V supply voltage in 180 nm technology. Spectre simulation confirms an IRR of 55.4 dB [18].

III. PROPOSED METHODOLOGY

An Operational Transconductance Amplifier (OTA) is a specialized amplifier that transforms voltage signals into current signals. Widely employed in analog circuit design, OTAs serve diverse purposes including filtering, oscillation, and amplification. Their attributes include high gain, broad bandwidth, and low power consumption, rendering them ideal for integration within integrated circuits. OTAs hold significant importance in signal processing and find widespread use in communication systems, audio amplifiers, and sensor interfaces. The proposed OTA is design using 90nm CMOS technology file in LTSpice XVII software. The design flow of the used methodology is display in Fig 1. The proposed OTA is design for WiFi and Bluetooth application at 2.4GHz frequency band.

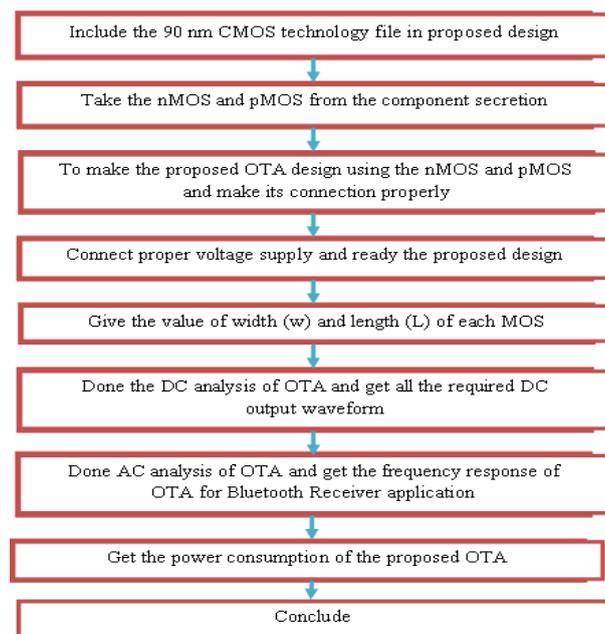


Fig. 1. Design Flow of proposed OTA Design

For design proposed OTA first include the CMOS 90nm technology file in the LTSpice XVII software after that take the nMOS and pMOS from the component section and make the proper connection of the proposed OTA. Now give the value of W and L to each nMOS and pMOS and done the dc analysis of the proposed design using the DC analysis section. After done the dc analysis done the AC analysis from the ac analysis section and check the power consumption of the proposed OTA design in the ac analysis.

IV. PROPOSED OTA DESIGN AND RESULTS

Fig 2 illustrates the proposed OTA design, structured on the cascade current mirror configuration. The cascade current

mirror configuration is frequently employed in Operational Transconductance Amplifiers (OTAs) to achieve both high gain and linearity. In this setup, multiple transistor stages are arranged in series, each replicating the current of the previous stage. This setup facilitates signal amplification with minimal distortion. By cascading multiple stages, the OTA's overall gain can be substantially boosted while preserving excellent linearity. Moreover, this configuration enhances output impedance matching and stability, rendering it suitable for a range of analog signal processing tasks including filters, oscillators, and amplifiers. The implementation and simulation of the CMOS OTA design are carried out using LTSpice software within a 90nm CMOS technology environment and the supply voltage is maintained at 3.8V.

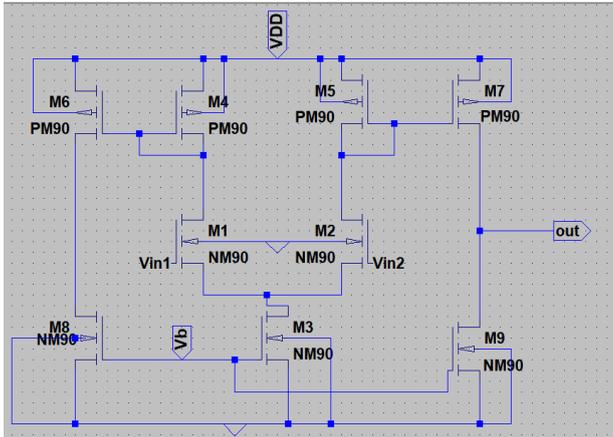


Fig. 2. Proposed OTA Design

The width (W) and length (L) of the proposed OTA is displayed in the table 1 and used input parameters for the presented OTA design using the LTSpice software is shown in the table 2.

TABLE I. DIMENSION OF THE TRANSISTOR FOR THE PROPOSED OPERATIONAL TRANSCONDUCTANCE AMPLIFIER DESIGN

Transistor	Width (W μm)	Length (L μm)
M1, M2	18	0.09
M3	37	1
M4, M5	5	0.09
M6, M7	21	0.09
M8, M9	18	1

TABLE II. USED INPUT PARAMETERS FOR SIMULATION OF PRESENTED OTA FOR BLUETOOTH/WiFi APPLICATION

Parameter	Value
CMOS Technology Used	90 nm
Power Supply (Vdd)	3.8V
Biasing Voltage (Vb)	-0.4V

A. DC Response of Proposed OTA

In the DC simulation analysis, a resistor was incorporated at the output terminal of the designed OTA. The configuration designed for the DC analysis of proposed CMOS OTA is presented in Fig 3.

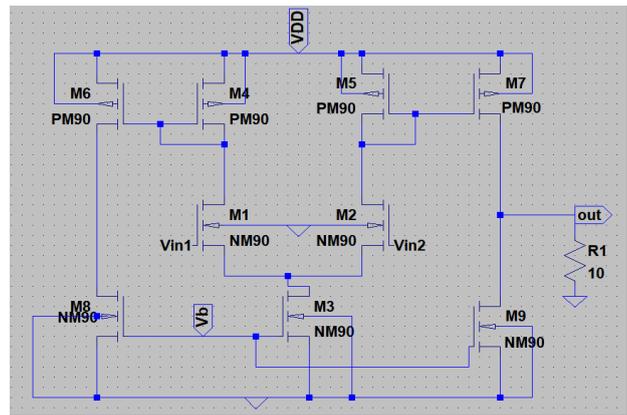


Fig. 3. Proposed OTA Configuration for DC Analysis

The total current range for the proposed OTA varies from 23.34mA to 60.38mA, resulting in an overall current of 37.04mA. The output current waveform of the proposed OTA is depicted in Fig 4.

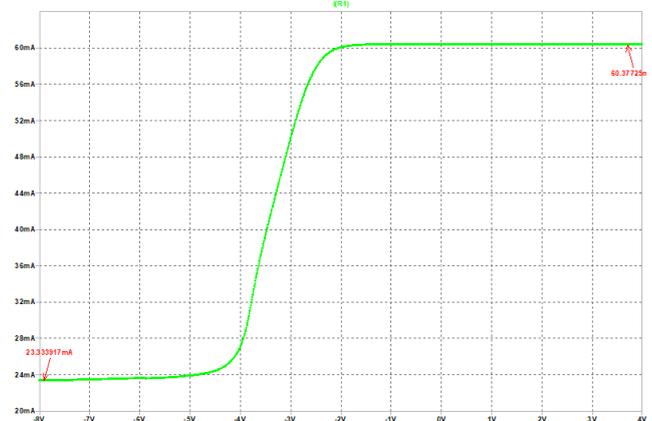


Fig. 4. Overall Output Current of Proposed OTA

B. AC Response of Proposed OTA

To analyze the AC response of the suggested CMOS OTA, a capacitor with a value of 1pF was introduced at the output terminal of the configured OTA. Fig 5 illustrates the configuration devised for the AC response of the OTA.

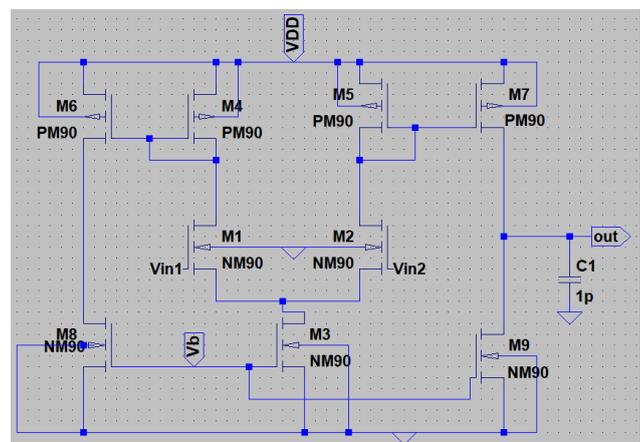


Fig. 5. Configuration of Proposed Operational Transconductance Amplifier for AC Response

The -3dB frequency response of the presented OTA is depicted in Fig 6, illustrating a frequency response at 2.4GHz with a magnitude of -73.35dB, a phase of 124.217°, and a

Group Delay of 47.48ps. Table 3 displays the frequency response of the proposed OTA alongside the acquired responses for various parameters.

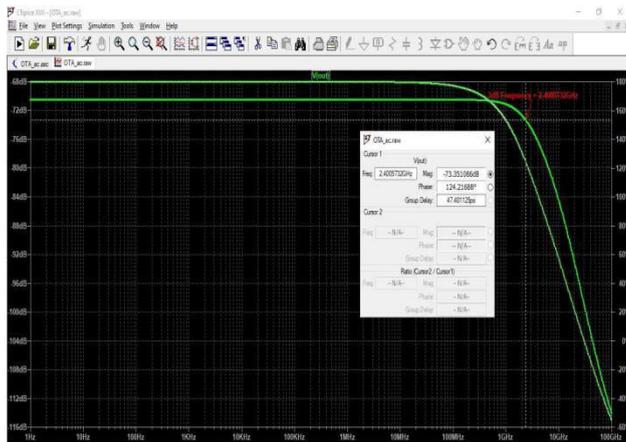


Fig. 6. Obtained Response of the Different Parameters and the Frequency Response of the Proposed OTA for Bluetooth/WiFi Application

TABLE III. RESULTS OBTAINED FROM THE AC RESPONSE OF THE PROPOSED OPERATIONAL TRANSCONDUCTANCE AMPLIFIER

Parameter	Value
-3dB Frequency Response	2.4GHz
Magnitude	-73.35dB
Phase	124.217°
Group Delay	47.485ps
Power Dissipation	40.13 mW

V. CONCLUSION

This study centers around a pivotal element in electronic circuits operational transconductance amplifier (OTA) design for applications in Bluetooth and WiFi technologies. This project is likely to explore the integration of CMOS technology, underscoring the importance of fine-tuning amplifier performance for optimal functionality in wireless communication systems. For wireless communication Bluetooth and WiFi technology is mainly used to connect the gadgets. This work introduces a cascade current mirror CMOS operational transconductance amplifier (OTA) tailored for wireless WiFi and Bluetooth applications operating within the 2.4GHz frequency band. The design of the OTA is implemented using CMOS 90nm technology and simulated in LTspice software with a 3.8V supply voltage. The resulting specifications include a magnitude of -73.35dB, a phase of 124.217°, a Group Delay of 47.48ps, and a power dissipation of 40.13 mW for the proposed OTA design.

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